Device for Checking the Surface Finish of Substrates by Tribometry Method

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Abstract

This article describes the tribometric device aimed at checking the concentration of organic impurities on the surface of dielectric substrates of type ST-50, BK-94, BK-100, C5-1 in the range 10^{-7} to 10^{-10} g/cm^2. Block and schematic circuit diagrams of the device, and its working algorithm have also been illustrated. Its design allows replacing the substrates (the test sample and the probe) within 60-80 seconds.

Keywords

Surface of Substrates; Organic Impurities; Tribometric Interaction; Degree of Surface Finish; Friction Factor; Schematic Circuit Diagram

Micro- and nanotechnologies demand high standards for surface finish of substrates. It happens because the adhesion parameters of thin-film structures are determined by the type and the concentration of atoms and molecules that contaminated the surface of substrates. Existing methods for checking the surface finish of substrates are based upon the usage of effects of wettability and of static friction. These methods for their operation demand the usage of special fluids and probes, which complicate their practical usage in the processes.

In this paper, it has been proposed to use the coefficient of sliding friction of surfaces of two substrates for checking the degree of surface finish of substrates. The substrates must be taken from the same batch, and their surfaces must have been formed in the same process. Moreover one of them serving as substrate-probe and is placed in point contact with the surface under test of the second substrate. This is ables to check the surface finish of substrates along the entire path of probe movement. The length of path can exceed the sizes of substrates. The tribometric device, which implements this method and checks the concentration of impurities in the range 10^{-7} to 10^{-10} g/cm^2 on the dielectric substrates of types ST-50, BK-94, BK-100, and C5-1 shown in Fig. 1.

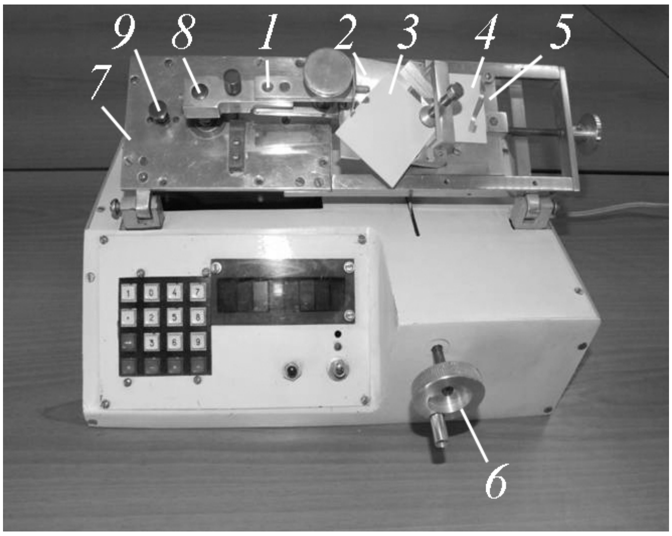

FIG.1. EXTERNAL VIEW OF THE DEVICE FOR CHECKING THE SURFACE FINISH OF SUBSTRATES.

For carrying out the measurement, rod *1* needs to be raised until stop. Then from this rod removing the substrate holder *2*, in the slots of which substrate-probe *3* is inserted. Test substrate *4* is placed in the substrate holder *5* and is fastened by special clamps. Thereafter, substrate holder *2* is put on rod *1* and released down to the working position (Fig. 1). The moment when the substrate-probe touches the surface of test substrate, rod *1* gets interlocked with the electrofixer. By rotating knob *6* between the planes of case cover and the base *7* makes an angle of 60 - 80°, which creates the conditions for substrates to slide relative to each other. Pressing force of substrates-probe depends upon the weight of substrate holder *2*. Sliding process starts when button of electrofixer *9* is pressed. Its design allows replacing the substrates (the test sample and the probe) within 60-80 seconds.

Block diagram of the device is shown in Fig. 2.

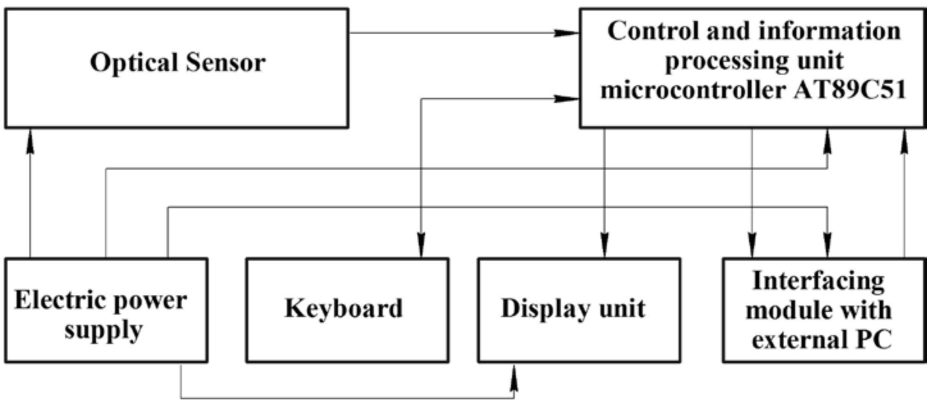

FIG. 2. BLOCK DIAGRAM OF THE DEVICE FOR EXPRESS-CHECKING OF DIELECTRIC SUBSTRATES SURFACE FINISH.

During the movement of substrate-holder, the raster disk, attached to shaft 8, rotates in the space between the infra red emitter and the photodetector, which forms the optical sensor. This results in the appearance of luminous flux pulses that get converted into electrical signals by the receiver. Duration of pulses thus obtained will depend upon the cleanliness level of the surface under study. Pulse duration of luminous flux is measured by the control and information processing unit. Measurement results are displayed on the seven-segment display. Any of the three measured values of luminous flux pulse duration and the arithmetic mean of these durations are selected and displayed on the display using the keyboard.

The device is operated in accordance with the program stored in the internal memory of microcontroller. Algorithm of this program is shown in Fig. 3.

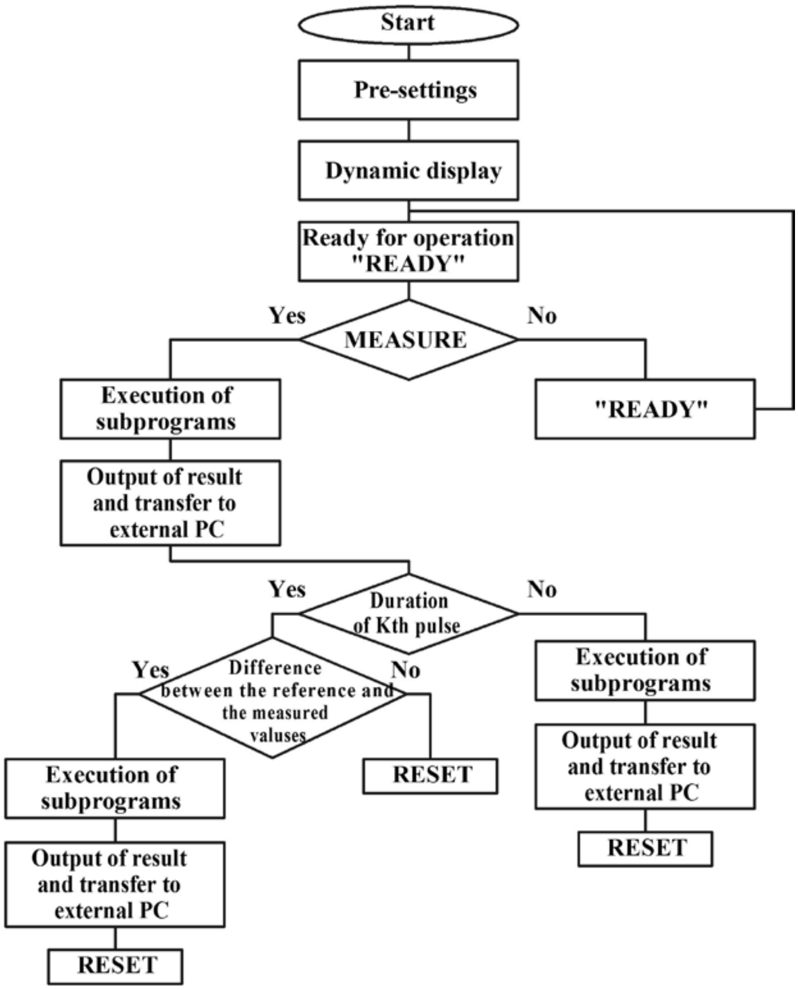

FIG. 3.OPERATION ALGORITHM OF DEVICE.

Pressing of key “MEASURE” leads to scanning of sensor status. In the event of swing from "1" to "0", the pulse duration of luminous flux is measured in the units of timing pulses until swing from “0” to “1” occurs. Measured value is converted from binary code into seven-segment code and is transmitted to the display circuit. Commands for selecting the Kth pulse and for calculating the difference between the reference and the measured values are entered from the keyboard, and thereafter the appropriate subprograms get executed. Calculated values are transmitted to the display circuit and to the memory of personal computer (PC).

Pressing of “RESET” button resets the internal registers of the microcontroller, clears the RAM of microcontroller, and the operation starts afresh with initial presettings in accordance with the algorithm.

Schematic diagram of device for checking the surface finish of substrates is shown in Fig. 4.

Circuit is based upon the microcontroller DD2 AT89C51, which performs the following operations:

- control of the device during operation;
- measurement of the pulse duration of luminous flux in the units of timing pulses;
- calculation of the arithmetic mean of the sum of three luminous flux pulses and deviations from entered values;
- display of the results of measurements and calculations on seven-segment LED display;
- interfacing between the device and the PC.

These operations are carried out in accordance with the program stored in the memory of microcontroller.

During measurements, LED VD7 generates the pulse of luminous flux, incident on photodiode VD5. At the same time, the swing from "1" to "0" is formed on the collector of transistor VT2, and in the absence of luminous flux pulse, the swing from "0" to "1" is formed. This signal arrives at the interrupt input of microcontroller. When the pulse of luminous flux starts acting on photodiode, the microcontroller starts the process of measuring the pulse duration of luminous flux by completing the time interval with precision pulses of quartz generator (pulse repetition period T=1μs) .

Display segment control signal is generated on the terminals of port P1. This signal arrives at the input of integrated circuit DD4 74ALS244, designed to match the microcontroller with the indicator. This signal is fed from the outputs of integrated circuit DD4 to the indicator HG1.

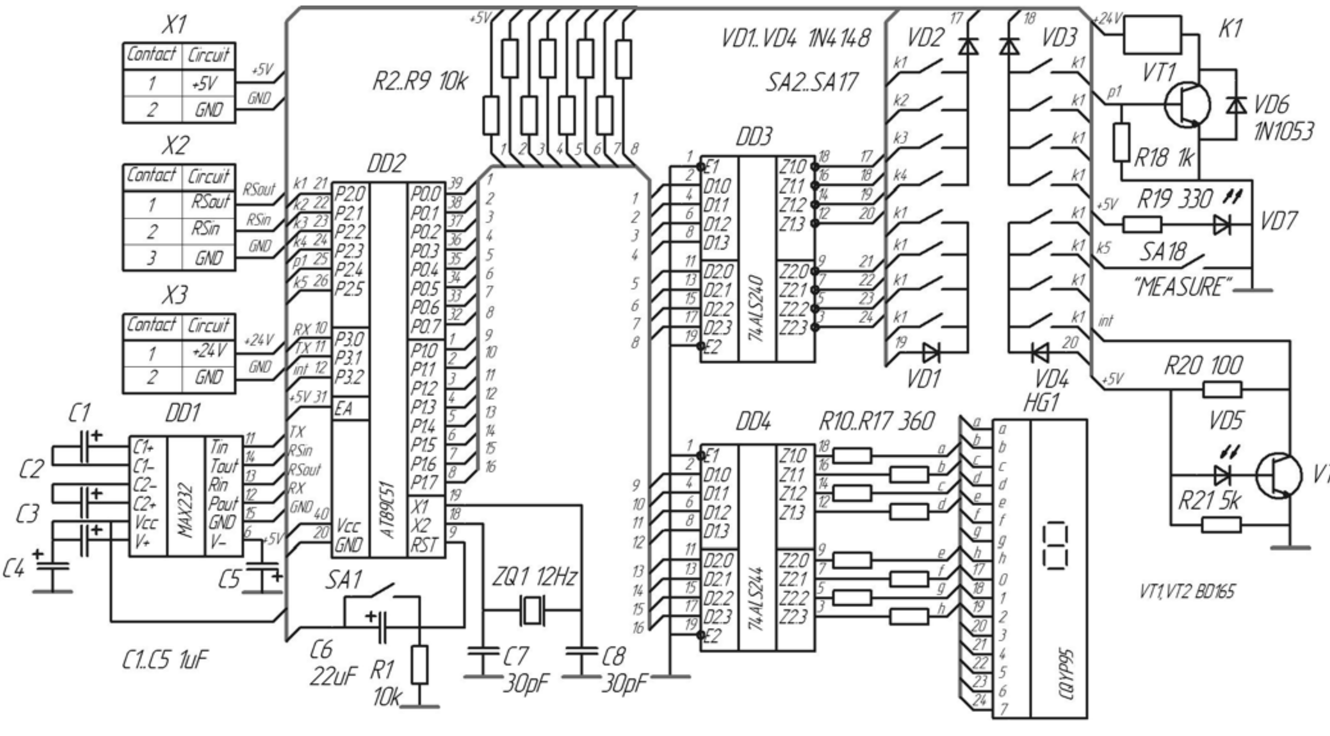

FIG.4. SCHEMATIC DIAGRAM OF THE DEVICE FOR EXPRESS-CHECKING OF DIELECTRIC SUBSTRATES’ SURFACE FINISH.

At bits 0 ... 8 of port P0, a signal is formed for control of the display bits and the keyboard inquiry. This signal arrives at the inputs of integrated circuit DD3 74ALS240 - signal shaper, which executes the inversion of signal, and then the transformed signal arrives at the display and the keyboard. Port P2 serves as an input for the keyboard inquiry signal. Diodes VD1-VD4 (1N4148) are designed to pass the keyboard inquiry signal from port P0 to port P2 through closed keys, but failing to pass in the opposite direction. The 9 - bit LED display CQYP95 is used as HG1 display. The keyboard has 16 keys, and function of each key is defined by the program.

A universal asynchronous serial receiver-transmitter (UART) has been implemented in the microcontroller DD1. This UART supports standard protocol RS-232C thereby ensuring its connection to the PC. Integrated circuit DD2, which exchanges the data with external PC used to provide this connection using standard protocol RS-232C.

Transistor VT1 operates in switching mode, which is needed to control the solenoid coil K1 of the rod fixer of substrate holder in upper position. When key "MEASURE" is pressed with 1 second delay, the transistor VT1 gets closed by the signal of logical zero level from the output 25 of microcontroller DD2. Also, the substrate holder with the test substrate moves to the lower position.

Components SA1, C6 and R1 form the reset circuit in automatic and manual mode. Automatic reset mode occurs each time when the device is turned-on. Whereas, in operation the manual reset mode is used by pushing the button SA1.

Resistors R2..R9 are designed for "adjusting" the terminals of port P0 to logical-1 level.

Diode VD6 is a damping diode required to protect the collector - emitter junction of transistor VT1 from voltage surges which occur in the solenoid coil K1 at the time of transistor's switching.

This method is very well adaptable to automation as the device can be connected with an external PC. It can be used as an express-control method directly on technological lines.

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